



# Affective speech prosody perception and production in stroke patients with left-hemispheric damage and healthy controls



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## ABSTRACT

**Purpose:** ‘Affective prosody’ defines the supra-segmental features of speech that, when manipulated, can change the type and intensity of emotion conveyed by the speaker. Although the right hemisphere is predominantly linked to the processing of affective prosodic cues, existing literature also suggests that damage to the left hemisphere can result in similar deficits. This study aims to demonstrate, and add to the evidence, that patients with left-hemisphere injury experience difficulties with affective prosodic perception and production, measured via a new combination of assessments and analyses. It is also hypothesised that aphasia severity will be correlated with impaired processing of affective prosody.

**Results:** Stroke and control participants differed significantly on prosody perception tests of matching auditory affective cues to visual images. Prosodic production was measured by participants vocalising different affective expressions of words and monosyllables – from which significant differences were found in perceptual judgements of emotion accuracy and intensity, and acoustic analyses of pitch range and variance. There were significant correlations between participants’ Western Aphasia Battery (WAB) scores, quality of life, and prosody production.

**Conclusion:** Individuals with left-hemisphere damage after stroke have impaired affective prosodic perception and production that may be associated with reduced quality of life.

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## 1. Introduction

Language is a complex and important skill; hence language disorders that affect about a third of people after stroke (Sinanović, Mrkonjić, Zukić, Vidović, & Imamović, 2011) can have a significant impact on quality of life (Hartelius, Elmberg, Holm, Löfberg, & Nikolaidis, 2008; Hogikyan & Sethuraman, 1999). The lexical and semantic aspects of communication – using correct grammar and punctuation, and combining related and meaningful words, dominate psycholinguistic research (Altmann, 2001). Another critical factor that has received less attention in the literature (Peppé, 2009) is prosody – minute distinctions in spoken language that determine what emotion and intent one conveys. There is an overall consensus that this “melody of language” (Monrad-Krohn, 1947) is modulated by variations in vocal pitch, intensity, quality, and temporal aspects, (Juslin & Laukka, 2001; Peppé, 2009). The total loss of, or disturbances in these expressive qualities of speech is in turn termed ‘aprosody’ (Ross, 1981), and has been

documented in many different forms, and linked to various neurological and psychiatric conditions (Bono et al., 2015; Ross, 2000).

Research on prosodic impairments after stroke-related neurological damage dates reasonably far back and has continuously been on the rise, with particular focus on the processing of affective aspects of prosody, as the majority of reports highlight this as a prominent issue for said clinical population (Barrett, Crucian, Raymer, & Heilman, 1999; Blonder, Pickering, Heath, Smith, & Butler, 1995; Blonder et al., 2005; Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992; Borod, Koff, Lorch, & Nicholas, 1985; Borod et al., 1998; Cancelliere & Kertesz, 1990; Heilman, Leon, & Rosenbek, 2004; Heilman, Scholes, & Watson, 1975; House, Rowe, & Standen, 1987; Leon et al., 2005; Nakhutina, Borod, & Zgaljardic, 2006; Orbelo, Testa, & Ross, 2003; Ross, 1981; Ross & Mesulam, 1979; Ross & Monnot, 2008; Ross, Thompson, & Yenkosky, 1997; Van Lancker & Sidtis, 1992; Wymer, Lindman, & Booksh, 2002).

### 1.1. Affective prosody after right-hemisphere stroke

Contrary to traditional perspectives that all language-related functions are modulated by the left side of the brain, it was proposed and subsequently strongly supported that the right

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hemisphere might be particularly dominant for processing affective prosody in speech (Ross, 1981, 1988, 2000). Case studies with unilateral right-hemisphere damage (RHD) stroke patients demonstrated impaired performance on several emotion-to-face-matching tasks, and facial and prosody discrimination tasks (Blonder et al., 1995). In addition to prosody comprehension deficits, some individuals showed increased trouble with imitating and expressing emotions (Heilman et al., 2004), and lost the ability to modulate their voice, speaking in monotonous tones irrespective of intended emotion (Ross & Mesulam, 1979), that was measurable by reduced pitch range in their speech (Blonder et al., 1995).

Larger-scale group studies have also reported that speakers with RHD produced emotional sentences with significantly less variation in pitch, measured acoustically as well as subjectively judged by listeners, who rated the RHD participant group as having poorer stress placement and emotion conveyance (Pell, 1999). Deficits in emotion comprehension in speech were found to be significantly present in RHD patients, even if comprehension of content remained intact (Heilman et al., 1975). This discrepancy between the content and emotional features of communication has been further supported by neural activation of the right lateral temporal lobe and right middle temporal gyrus when listening to affective tones of voice in sentences, and the absence of this activity once attention was shifted towards more semantic content (Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003). Impairments across multiple forms of emotion communication – including facial expressions, words describing emotions, and affective prosody – have also been documented in individuals with RHD, in terms of both perception (Borod et al., 1998) and production (Borod et al., 1985).

### 1.2. Affective prosody after right versus left hemisphere stroke

Despite RHD-related deficits being presented as the main findings in many studies, participants in left-hemispheric damage (LHD) groups also display poor affective prosody processing abilities, albeit not to the same extent of severity (Borod et al., 1992; Cancelliere & Kertesz, 1990; Heilman et al., 1975; House et al., 1987; Orbelo et al., 2003; Pell, 2006; Schlanger, Schlanger, & Gerstman, 1976; Van Lancker & Sidtis, 1992).

Early studies reported no significant difference between LHD and RHD patients on sentence-based emotion identification tasks (Schlanger et al., 1976) and recognition of affective prosodic stimuli (Van Lancker & Sidtis, 1992), as well as both patient groups displaying speech with depressed-like qualities despite the absence of any clinical diagnoses (House et al., 1987). Borod et al. (1992) also revealed that participants with RHD and LHD consistently scored lower than healthy controls on the literal identification and discrimination of emotion words. Whilst those with LHD were able to perform better than their RHD counterparts on the tasks with single word presentations, their performance fell to relatively comparable levels with those with RHD when presented with emotion words that were embedded in full sentences. Patients with LHD and RHD were also similarly impaired at identifying affective prosody in words, compared to normal ageing elderly individuals (Orbelo et al., 2003). However, unlike the RHD group whose scores worsen as the tasks progress to monosyllabic and asyllabic stimuli, those with LHD seem to be able to maintain a consistent level of performance regardless of task.

In contrast, instead of a LHD/RHD dichotomy, other studies have focused on how patients with lesions of either hemisphere demonstrate different prosody-related difficulties. It has been demonstrated that damage to one's basal ganglia, anterior temporal lobe, and/or insula, irrespective of hemisphere, contributed to impairments in the expression, repetition, and comprehension of affective prosody (Cancelliere & Kertesz, 1990). An early report of

contrasting deficits details how individuals with RHD were markedly worse on a discrimination test using synthetic sounds with no communicative meaning, suggesting an inability to process the acoustic features of a sound, whereas those with LHD performed significantly worse on a sound identification test, suggesting an inability to recognise what the sound was and attribute meaning to it (Faglioni, Spinnler, & Vignolo, 1969). Van Lancker and Sidtis (1992) also demonstrated how LHD and RHD patients differentially utilised pitch range as an acoustic cue to recognise emotions, yet both methods still led to errors in their judgements. Those with LHD seem to have particular trouble with aspects of prosody specifically linked to language and its contents, and it has been proposed that they exhibit a decreased ability to concurrently process and integrate the segmental and supra-segmental aspects of the speech stimuli (Pell, 2006). For individuals diagnosed with aphasia as a result of LHD, the disruption to their language processing could perhaps also add to their difficulties with prosody processing (Ross et al., 1997). This is potentially supported by the substantial overlaps observed in the categorisation of the aphasias and the aprosodia conditions (Ross, 1981, 2000).

All in all, there is evidence that both LHD and RHD as a result of stroke can impair the perception and production of affective prosody, as well as facial expressions and the lexical processing of emotion (Borod, Bloom, Brickman, Nakhutina, & Curko, 2002). Perception of affective prosody has mainly been assessed using emotional word discrimination tasks, and face-to-emotion matching tasks that engage both visual and auditory modalities. Production of affective prosody has been measured by examining the accuracy of emotional imitations, as well as acoustically analysing and subjectively rating spontaneous speech. The current study aims to evaluate the effectiveness of a range of methods used to assess and analyse prosody perception and production. It also aims to emphasise the difficulties in prosody processing experienced particularly by those with post-stroke LHD, and to stress that speech rehabilitation practices for this population should emphasise an equal focus on aprosodia.

## 2. Material and methods

### 2.1. Participants

Eleven participants with LHD post-stroke (6 males, 5 females), and 15 control participants (4 males, 11 females) took part in the study. Participants were recruited via the University of Auckland's Centre for Brain Research (CBR) volunteer register, as well as the CBR CeleBRation Choir for people with neurological conditions. The criteria for participation included males and females aged 30–80 years, with no neurological impairments for the control group, and no additional medical conditions for the stroke group (except for mild epilepsy in one participant). Thirteen out of 15 of the control participants were right-handed. In the stroke group, 7 were right-handed, 1 was left-handed, and 3 have had to learn to use their left hand as the dominant one due to hemiplegia.

All participants completed a Brief Screen for Cognitive Impairment (BSCI), and the Hospital Anxiety and Depression Scale (HADS), which had separate total scores of 0–21 for anxiety and depression. All control participants had normal levels of anxiety and depression (scored within 0–7). Three stroke participants had borderline abnormal levels of anxiety (scored within 8–10), and one stroke participant had a borderline abnormal level of depression (scored within 11–21). Results from Mann-Whitney U tests show that the two participant groups did not differ on age range, measures of cognitive functioning, anxiety, and depression (Table 1).

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